VII. WHAT IS THE EMPIRICAL RELATIONSHIP BETWEEN NON-CASH PURCHASES AND SPOT MARKET PRICES?

In this section, we investigate the empirical relationship, in the short run, between non-cash purchases of fed cattle and spot market cattle prices. In this regard, we draw a sharp distinction between two specific "levels" at which this relationship might be examined. We refer to the first as the "plant level" relationship. It is addressed in section VII.1 and pertains to the short-run relationship between non-cash purchases by a given plant and the spot market prices paid by that plant *relative to the regional market's average price*. We call the second "level" at which the relationship might be examined the "regional market level." It is addressed in section VII.2 and pertains to the short-run relationship between the use of non-cash cattle at the regional level and the regional average spot market price.

VII.1. The Empirical Relationship at the Plant Level

Evidence reviewed in section V suggests that packers have a fairly accurate idea of the volume of non-cash cattle deliveries they will receive over the near-term future. This is due to the fact that the packer has discretion over the scheduling of delivery of some types of non-cash purchases (forward contract and packer fed cattle) and to the fact that the non-cash cattle deliveries that are scheduled by feeders (marketing agreement cattle) require that a certain amount of advance notice be given to the packer. Thus, when a packer enters the spot market with the intention of purchasing cattle for slaughter over a given period of time; a given week, say; it typically knows the volume of non-cash cattle deliveries already scheduled for that week. For any given packer, moreover, this volume of pre-committed supplies tends to vary from week to week. The following graphical model shows how the packer's spot market cattle purchases and average spot market price is likely to vary in response to week to week fluctuations in the volume of non-cash cattle deliveries.

Figure 1 depicts the residual supply curve of spot market cattle facing an individual packer. Labeled AAC_S, for average acquisition cost of spot market cattle, this curve represents the regional spot market's overall supply net of spot cattle demands by other packers in the region. Defined in this way, the residual supply curve consists of the locus of price - quantity combinations available to the packer in its spot market dealings for the time period under consideration. The fact that the curve slopes upward reflects our assumption that the packer possesses at least some degree of market power in its regional spot cattle market: The price it must pay is not independent of the number of spot cattle it purchases. For given market conditions, purchasing a greater number of cattle requires that the packer bid more aggressively causing the average spot cattle acquisition cost to rise, at least slightly.[27] Of course, the position of the packer's residual supply curve can shift with shifts in regional supply or with changes in rival packers' spot marketing conduct for the period. Because residual supply, representing average cattle acquisition cost, is upward sloping, marginal cattle acquisition cost, also depicted in Figure 1 and labeled MAC_S, lies everywhere above it.

Figure 2 depicts the packer's marginal slaughter/processing cost for cattle, labeled MPC and drawn so as to indicate an approximately constant marginal processing cost out to plant "capacity" at which point marginal cost rises sharply. Figure 3 depicts the output demand curve, or average revenue curve (labeled AR), that the packer faces. As drawn here, with a slight downward slope, the packer is assumed to possess a small degree of output market power: If the packer were to sell more output, it would drive the price down slightly. If, instead, the packer's output price were independent of its sales, demand would be horizontal. Marginal revenue, denoted MR in Figure 3, lies everywhere below demand.[28]

Now consider a packer with a given volume of non-cash cattle deliveries already committed for the decision period. The acquisition cost of these cattle is already sunk and so will not affect the packer's spot market purchase decision. The packer's relevant marginal cost curve is therefore MPC alone, out to the pre-committed non-cash delivery volume, and is given by the vertical sum of MPC and MAC_S beyond that point. Figure 4 shows two such marginal cost curves, MC_1 and MC_2, corresponding to pre-committed non-cash supply volumes CS_1 and CS_2, respectively. In either case, the packer will purchase spot market cattle in numbers sufficient to bring total slaughter volume to the profit maximizing point at which MC = MR. With pre-committed supply volume CS_1, profits are maximized with total slaughter of TS_1 achieved with spot market purchases of TS_1 - CS_1. Alternatively, suppose that the packer entered the decision period with the larger volume of pre-committed supplies, CS_2, while the position of its residual spot market supply remains unchanged. Then optimal total slaughter would be TS_2, achieved with spot market purchases of TS_2 - CS_2. Because TS_2 - CS_2 is less than

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[27]A number of empirical studies have found evidence that packers possess at least some degree of "market power" in their cattle input markets. For an example, see Schroeter (1988). Again, this simply means that a typical individual packer perceives an upward sloping relationship between the number of spot market cattle procured, in any given time period, and the average acquisition cost of these cattle. We do not suggest that the existence of this market power is attributable, in any sense, to the use of non-cash procurement methods. Indeed, the Schroeter study found evidence of market power during a time period (1951-1983) in which the use of non-cash procurement methods was far less prevalent than it is now.

[28]The model's conclusions require that AAC_S and MAC_S slope upward and at least one of the following: MR slopes downward or MPC slopes upward at the equilibrium point.

TS_1 - CS_1, and because the packer's residual supply is upward sloping, the packer will pay a lower average price for spot market cattle with pre-committed deliveries CS_2 than with CS_1: For a given packer, *facing a given residual supply curve of spot market cattle*, higher volumes of pre-committed non-cash cattle deliveries will tend to be associated with lower prices paid on the spot market.

Notice the qualification emphasized with italics in the last sentence. Its importance can be seen by considering two simple examples. Suppose, on the one hand, that the scheduled non-cash cattle deliveries of all packers in the region were to increase by the same factor, say 20%, from one week to the next. The resulting drain on the number of cattle that would otherwise be available on the spot market would shift back the residual supply curves facing each packer. Thus, while each packer may well purchase fewer spot market cattle as a result of its increase in anticipated delivery numbers from non-cash sources, it is not obvious that they would be able to make those purchases at lower prices on average. Now, on the other hand, suppose that a given packer anticipates a 20% increase in non-cash cattle deliveries over last week's figures *and* that this increase will be offset by a reduction in the scheduled non-cash cattle deliveries to other packers in the regional market. In this case, one would expect little or no shift in the residual supply curve facing the packer anticipating increased non-cash deliveries. The analysis of the previous paragraph would apply and the packer with an increase in the scheduled volume of non-cash deliveries would purchase fewer spot market cattle at lower average prices than the previous week.

Consideration of the two scenarios described above suggests that prices paid on the spot market are actually a function of the packer's scheduled non-cash delivery volume *relative to rival packers' scheduled non-cash delivery volumes*. It is when a packer anticipates deliveries of non-cash cattle that are high relative to its rivals' degrees of reliance on non-cash supply sources for the same period that we might expect the packer to make spot market purchases at low prices. Moreover, "low prices," in this context, is also a relative concept. In any given week in any given regional spot market, there is in fact an entire distribution of prices paid for fed cattle; a distribution which shifts, from week to week, due to changes in market conditions. By a *low* price, we mean a price that is low relative to the mean of the price distribution representative of current market activity. These observations lead to the following hypothesis:

> **Hypothesis 1: Packers tend to pay spot market cattle prices that are "low" compared to the regional market's average price when they anticipate near-term- future deliveries of cattle from non-cash sources that are "high" relative to total slaughter volume and relative to rival packers' degrees of reliance on non-cash supply sources over the same period.**

We will undertake an investigation of this hypothesized relationship between spot market prices paid and packers' scheduled non-cash delivery volumes using a multiple regression analysis of a data set with observations corresponding to individual spot market purchase lots. The dependent variable, RPRICE, is the "relative price" paid for the lot, defined as the price of the lot's cattle; on an FOB feedyard, live weight basis; minus the weighted average price of steers reported by AMS for the Oklahoma-Texas panhandle region on the day of purchase of the lot, in $/cwt. Defined in this way, RPRICE can be interpreted as the lot's price's departure from a representative "average" price for the day of purchase.

The key explanatory variable will capture the effect on relative spot market prices of changes in the relative volume of scheduled deliveries of cattle from non-cash sources. To understand how this variable should be properly measured, some timing considerations must first be addressed. Again, when a packer purchases cattle on the spot market "today," it is with the intention of slaughtering those cattle over some future period, or "planning horizon." So, as argued using the graphical model presented above, spot prices paid today should be connected to the packer's relative degree of reliance on non-cash purchases over the planning horizon. Of course, there is no obvious and clear-cut way to define the planning horizon relevant to today's spot market pricing conduct for a given packer. We thought a reasonable approach to the problem would be to specify alternative plausible planning horizons and examine the nature and strength of the econometric relationship between spot cattle prices, on the one hand, and the relative degree of reliance on non-cash purchases during each of these planning horizons, on the other. So, in our analysis, the relative price of a lot of spot market cattle purchased today by a given plant will be explained in terms of that plant's relative degree of reliance on non-cash purchases over one of the following planning horizons.

Planning horizon 1: The starting and ending date of planning horizon 1 correspond, respectively, to the earliest kill date and the latest kill date for the lots of spot market cattle purchased by the plant today.[29]

Planning horizon 2: The period of seven days following today.

Planning horizon 3: The period of fourteen days following today.

The non-cash supply variable, which we call "relative ratio" and denote RRATIO, can then be defined in terms of any one of the three alternative planning horizons. But it remains to describe specifically how RRATIO is constructed. For each day on which spot market purchases were made, and for each packer, we first calculate the value of "RATIO," the proportion of total slaughter, over one of the three planning horizons, that

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[29]For , the earliest kill date for cattle purchased on a given day averaged 4.94 days after the purchase day. The latest kill date averaged 13.06 days after the purchase day. The corresponding figures for (4.64, 11.24), (4.07, 9.15), and (4.54, 9.49) were similar.

is attributable to non-cash purchases. Then, for each spot market lot purchased on that day, take the value of RRATIO to be the purchasing packer's value of RATIO expressed as a deviation from the average value of RATIO for the four Texas plants on that purchase day. For example, suppose that for a given spot market purchase day, the four plants' total slaughter volumes over the next seven days contained the following proportions of cattle from non-cash sources: 0.15, 0.30, 0.21, 0.38 for plants A, B, C, and D respectively. Then, using planning horizon 2 as the basis for definition, a lot purchased by plant A on that day would be assigned an RRATIO value of -0.11 (= 0.15 - (0.15 + 0.30 + 0.21 + 0.38)/4). With RRATIO defined in this way, a "high" ("low") value for a given lot means that the plant purchasing the lot anticipates a degree of reliance on non-cash purchases, over the planning horizon, that is "high" ("low") relative to that of its rivals.[30]

Besides RRATIO, additional explanatory variables were included to control for other sources of systematic variation in prices across plants and through time, and to account for the effects of a variety of lot "quality" indicators which may influence price. These additional variables are defined below.

HEAD =	number of cattle in the lot (head).
YIELD =	the lot's total hot weight divided by total live weight (%).
PCTPC =	percentage of the lot grading prime or choice (%).
PCTYG13 =	percentage of the lot achieving yield grades 1, 2, or 3 (%).
MILES =	the distance the cattle were shipped to the plant (miles).
MILES2 =	the square of the distance the cattle were shipped to the plant (miles^2).
HEIFER =	a dummy variable equal to 1 if the lot consists of heifers, and equal to 0 otherwise.
MIXED =	a dummy variable equal to 1 if the lot consists of a mixture of steers and heifers, and equal to 0 otherwise.
CARCASS =	a dummy variable equal to 1 if the lot was priced on a carcass-weight basis, and equal to zero if it was priced on a live-weight basis.
AWS =	the lot's average carcass weight, if the lot consists of steers; equal to 0 otherwise (lb.).

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[30]Each of the four plants has a value of RRATIO for each of the spot market purchase days represented in the final sample. In the actual implementation of the estimation procedure, these values were normalized by subtracting the plant's sample average value for RRATIO. Because the menu of explanatory variables also includes plant-specific dummy variables, this normalization does not affect estimates of the coefficient of the RRATIO variable. As Table V.1 reveals, there were relatively significant differences among the plants in their overall degrees of reliance upon non-cash cattle, however. By normalizing RRATIO in this way, we load any price effects of cross-plant differences in the average propensity to use non-cash supplies, along with the effects of any not-otherwise-accounted-for plant-specific characteristics, onto the coefficients of the plant-specific dummy variables.

AW2S = the square of the lot's average carcass weight, if the lot consists of steers; equal to 0 otherwise (lb.^{2}).

AWH = the lot's average carcass weight, if the lot consists of heifers; equal to 0 otherwise (lb.).

AW2H = the square of the lot's average carcass weight, if the lot consists of heifers; equal to 0 otherwise (lb.^{2}).

AWM = the lot's average carcass weight, if the lot consists of a mixture of steers and heifers; equal to 0 otherwise (lb.).

AW2M = the square of the lot's average carcass weight, if the lot consists of a mixture of steers and heifers; equal to 0 otherwise (lb.^{2}).

a dummy variable equal to 1 if the lot was purchased by the plant, and equal to 0 otherwise.

a dummy variable equal to 1 if the lot was purchased by the plant, and equal to 0 otherwise.

a dummy variable equal to 1 if the lot was purchased by the plant, and equal to 0 otherwise.

The list of explanatory variables also included dummy variables identifying the purchase-day-of-the-week (MON, TUE, WED, THU) and dummy variables identifying the purchase week of the sample.

The model was estimated by ordinary least squares.[31] The regression results for the case in which RRATIO is defined using planning horizon 1 are reported in Table VII.1.1. The results with respect to explanatory variables other than RRATIO are of secondary interest, so a discussion of these results is relegated to Appendix C.[32] The table below contains the point estimates, standard errors, and t-statistic values for the coefficient of RRATIO defined using each of the three planning horizons.

Planning horizon	Parameter estimate	Standard error	t-statistic for H_0: parameter = 0
1	-0.2149	0.0634	-3.391
2	-0.4133	0.0579	-7.141
3	-0.2224	0.0712	-3.125

[31]The original data set recorded 24,425 spot market purchases of lots of fed cattle by the four Texas plants combined. Of these, 2342 had to be deleted because the FOB feedyard price, which is required to determine the value of the model's dependent variable, was not recorded. Three lots were dropped because of missing or obviously incorrect data entries. An additional 812 were deleted because the recorded entry for the lot's total delivered cost (which should include transport cost) was less than or equal to the entry for FOB feedyard cost (which should exclude transport cost). While this inconsistency does not necessarily mean that the value for FOB feedyard price (FOB feedyard cost divided by the lot's total live weight) is in error, it at least casts some suspicion on its accuracy. To be usable in the analysis, lots had to have been purchased on days for which an AMS report of steer prices was available. As a practical matter, this restricted the sample to lots purchased on week days. Also, because the planning horizons are forward-looking, the sample does not contain information sufficient for the calculation of the value of RRATIO on some of the purchase days toward the end of the sample period: Lots purchased during the sample's last two weeks were dropped. These last two requirements led to the elimination of another 814 lots, bringing the usable total down to 20,454. Finally, the manner in which RRATIO is defined requires that attention be limited to the lots purchased on days on which all four plants registered spot market purchases. During the sample period, the Excel-Friona, Excel-Plainview, IBP, and Monfort plants made spot market purchases of fed cattle on 224, 214, 220, and 218 days, respectively. But there were only 148 days in the sample on which all four plants purchased on the spot market. Restricting attention to lots purchased on just these 148 days brings the sample to a final size of 17,853 observations.

[32]Estimates of the coefficients of the control variables were quite similar across models differing in the planning horizon used as the basis for definition of RRATIO. Appendix C also discusses the rationale for inclusion of each of the explanatory variables defined above.

Based on results from any one of the three regressions, the null hypothesis that the coefficient of RRATIO is zero can be rejected in favor of the one-sided alternative that it is negative at the 0.1% significance level. These findings are statistical evidence in support of hypothesis 1: When packers anticipate near-term-future deliveries of non-cash cattle that are "large" relative to total slaughter volume and relative to their rivals' degrees of reliance on non-cash purchases for the same period, they tend to pay spot market prices that are low relative to the market's current average price. We can base an estimate of the magnitude of the effect on the parameter estimates reported in the table above. Over the entire sample period, the proportion of the four plants' combined fed cattle slaughter that was attributable to non-cash purchases was approximately 0.29. Imagine that, from one week to the next, plant A experiences an increase in its near-term-future non-cash cattle proportion from 0.29 to 0.39 while, at the same time, there are offsetting changes in the use of non-cash purchases by the other plants. In this case, plant A's value of RRATIO would increase by 0.1. The parameter estimates suggest that the spot market price effects of this change would be a decrease of 0.021 to 0.041 \$/cwt. Thus, the magnitude of the effect is quite small.

It should be emphasized that the results of this analysis cannot be used to infer the likely effects of an across-the-board decrease in the degree of reliance on non-cash purchases. A uniform reduction in non-cash proportion by all four plants would leave values of the RRATIO variable unaffected. In this analysis, our objective was to determine whether a single plant's departure from the currently representative degree of reliance on non-cash purchases translates into a tendency to pay spot market prices that differ from average prices. What we have found is that when plants purchase spot market cattle for a planning horizon for which anticipated deliveries of non-cash cattle are "high" relative to their rivals' degrees of reliance on non-cash purchases, they tend, other things equal, to pay prices that are slightly below average.[33]

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[33]The coefficients associated with the plant dummy variables capture the not-otherwise-accounted-for price effects of plant-specific characteristics, including any price effects that may be attributable, in some way, to each plant's overall propensity to use non-cash procurement methods. We note that the ranking of plants, from the least to the most reliant on non-cash procurement methods is the same as the ranking of plants from the highest to the lowest estimated dummy variable coefficients:

of the fed cattle slaughtered over the period of investigation were attributable to non-cash procurement methods; dummy variable coefficient estimate =

was omitted from the regression)),

So, for example, once account is taken of all of the factors explicitly represented in the regression equation reported in Table VII.1.1,

However, we do not believe that this constitutes sufficient support for the conclusion that overall degree of reliance on non-cash procurement

VII.2 The Empirical Relationship at the Regional Level

Since some prior research has also investigated the relationship between the use of non-cash procurement methods and spot cattle prices at a more aggregate level, finding a negative relationship, we undertake similar regression analyses in order to see if the negative relationship is present in our data too. This leads to the following hypothesis:

> **Hypothesis 2: A multiple regression analysis of the relationship between a regional market's average spot cattle price (as the dependent variable) and the region's aggregate use of cattle from non-cash sources (as one of the independent variables) will reveal a negative relationship between the two, other things equal.**

To investigate the statistical relationship, in the short run, between average spot market cattle prices in the Texas panhandle region and the regional use of non-cash procurement methods, we use weekly data to regress price on the number of spot market cattle purchased by the four Texas plants, a measure of the packer's output price, a time trend, and a non-cash supply variable. The behavioral interpretation that seems most natural for such a regression is that of a packer demand curve for spot market cattle. As we shall see, however, ordinary least squares and two-stage least squares estimation fail to produce negative (much less, *significantly negative*) estimates of the coefficient of spot market quantity, as one would expect with a conventional downward sloping demand curve. We do not claim to have adequately characterized spot market demand with this formulation. Our objective in this exercise is merely to demonstrate that these data embody a statistical relationship between the contemporaneous values of regional price and non-cash supply usage similar to that found in other data sets using similar specifications: Spot market price tends to be low during weeks in which the use of cattle from non-cash sources is relatively high. The policy significance of this statistical relationship depends on the nature of the economic mechanism that is responsible for generating it. In the section VIII.2, we will propose and investigate an economic mechanism which may be the source of the empirical regularities revealed by the regression analysis carried out here.

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methods is the *cause* of its tendency to pay spot market prices that are "low" on average. Other plant-specific factors may be at work.

Specifically, we estimate regressions of the form of equation (3) using data for the 66 weeks of our sample:[34]

$$\text{average price in week } t = \gamma_0 + \gamma_1\, AVGVAL_t + \gamma_2\, Q_t + \gamma_3\,(\text{non-cash supply deliveries in week } t) + \gamma_4\, WEEK_t + \gamma_5\, WEEK2_t + \varepsilon_t \qquad (3)$$

The dependent variable represents the region's average spot market cattle price in week *t* and is measured in each of the four ways to be described in detail below. $AVGVAL_t$ is a measure of the price of the packer's output in week *t* calculated as follows: For each reporting day in week *t*, the AMS daily box beef cutout values (AMS LS411) for light choice, heavy choice, light select, and heavy select are averaged. These daily averages are themselves averaged over all reporting days in week *t* to obtain $AVGVAL_t$. Q_t is the number of steers and heifers purchased on the spot market by the four Texas plants in week *t*.[35] The terms in $WEEK_t$ and $WEEK2_t$ represent a quadratic time trend. $WEEK_t$ is a simple time trend variable. (That is, $WEEK_t$ equals 1 in week t = 1, equals 2 in week t = 2, etc.) And $WEEK2_t$ is the square of $WEEK_t$. Finally, ε_t is a random error term.

The non-cash supply variable is measured in two different ways: by the total number of head of steers and heifers procured by non-cash methods (forward contract, marketing agreement, and packer fed) and delivered to the four Texas plants in week *t* ($CSTOT_t$), and by this number expressed as a proportion of the four plants' slaughter in week *t* ($CSRAT_t$).

Of the four alternative measures of the dependent variable, two, $AVGSPR_t$ and $AVGHPR_t$, are defined using AMS reported prices. To construct the value of $AVGSPR_t$ for a given week, start with the reported weighted average price of steers in the 1100-1250 lb. live weight category, in lots grading 35-65% select or choice, for the Oklahoma-Texas panhandle region, and the number of head upon which the reported price is based, for each reporting day in week *t* (AMS LS720). $AVGSPR_t$ is then

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[34]The data set contains essentially complete records on the lots of cattle *killed* by the four Texas plants during a 67 week time span from the week of February 5, 1995, through the week of May 12, 1996. Information on the lots *purchased* during the last week of the sample was incomplete, however, so it had to be dropped in this analysis.

[35]Here we are implicitly assuming that the relevant regional market quantity is the number of fed cattle purchased by the four packing plants in our sample. To be sure, other plants make spot market purchases from feedyards in the Texas panhandle region. And the four plants in our sample occasionally ship cattle from feedyards hundreds of miles away. But it is probably safe to assume that the purchases of these plants is a good approximation for the trading volume in the relevant regional cattle market.

obtained as a head-weighted average of the daily average prices for reporting days in week *t*. The $AVGHPR_t$ series is similarly constructed, but starting with daily average heifer (1000-1150 lb., 35-65% SE/CH) prices (AMS LS720).

The other two measures of regional average price were constructed from price data for the four Texas plants in our sample. For each week *t*, $AVGCPR_t$ was calculated as a head-weighted average of the prices paid for spot market cattle (steers and heifers only, FOB feedyard, $/cwt. live weight basis) by the four Texas plants.

To motivate the construction of the final regional price series, $ADJCPR_t$, first consider that the $AVGSPR_t$ and $AVGHPR_t$ series arguably represent prices for a given quality of cattle through time.[36] $AVGCPR_t$, on the other hand, is based on prices paid for the cattle actually purchased by the four plants. If there were systematic variation, over time, in the quality of cattle purchased, the values of AVGCPR would not be comparable across weeks. Our fourth measure of regional average prices, $ADJCPR_t$, is the result of an effort to adjust the prices paid by the four Texas plants for possible week-to-week variation in spot market cattle quality.

The construction of the ADJCPR series begins with a regression equation explaining the price of spot market cattle (FOB feedyard, live weight basis) in terms of lot characteristics similar to those used in the price regression undertaken in section VII.1, and purchase week dummy variables. The results of this regression are presented in Table VII.2.1. Because this regression is quite similar to the one undertaken in section VII.1, we omit a detailed discussion of its results.

Now consider two lots of cattle with identical lot characteristics (number of head, yield, percentage grading prime or choice, etc.) but purchased in two different weeks of the sample period. The model predicts that these two lots would sell at prices that differ by the difference between their purchase week dummy variable coefficients. Thus, this difference is the model's estimate of the difference between the two weeks' prices for cattle of constant quality. Finally, to construct the adjusted price series, we set the value of $ADJCPR_t$ for the last week of the sample (the week of May 5, 1996) equal to the value of $AVGCPR_t$ for that week. We can think of the sample's last week as the "base" week, the one for which no purchase week dummy was included in the regression. To obtain the values of the $ADJCPR_t$ series for the remaining weeks of the sample, we start with its base week value and add the estimates of the coefficients of the purchase week dummy variables for each week. The result is a series of estimates

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[36]The particular quality category; 35-65% select or choice, 1100 - 1250 lbs. (for steers) or 1000 - 1150 lbs. (for heifers); is quite broad, however, incorporating the majority of lots sold on the spot market.

of the prices at which the cattle representative of the sample's last week's spot market purchases would have sold in each of the other weeks of the sample period.[37]

The decision of which procedure to use in estimating equation (3) depends on properties of the error term, ε_t, representing not-otherwise-accounted-for factors influencing the determination of cattle price in the regional spot market. If the error term is uncorrelated with the equation's explanatory variables, ordinary least squares (OLS)

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[37]All four measures of regional price; AVGSPR, AVGHPR, AVGCPR, and ADJCPR; behaved very similarly in the regressions reported in this section and, as shown by the tables below, had very similar summary statistics and displayed very high simple correlation coefficients between all pairs of the price variables.

There are two points worth noting about the degree of similarity of these series. First, the AMS reported price series appear to be quite representative of the prices paid on the spot market, at least by the four plants in our data set. Second, there apparently was little or no systematic variation in spot market cattle quality over the sample period because the ADJCPR series, which adjusts prices for quality variation, is very similar to the AVGCPR series, which is merely an average of prices actually paid irrespective of quality.

Summary statistics for the four regional price variables:

	Mean	Std. dev.	Minimum	Maximum
AVGSPR	64.877	3.795	55.577	74.993
AVGHPR	64.883	3.802	55.548	75.000
AVGCPR	64.695	3.786	55.508	74.796
ADJCPR	64.763	3.784	55.599	74.901

Simple correlation coefficients among pairs of regional price variables:

	AVGHPR	AVGCPR	ADJCPR
AVGSPR	0.99979	0.99965	0.99932
AVGHPR		0.99953	0.99928
AVGCPR			0.99975

will produce consistent estimates.[38] On the other hand, if the error term is correlated with one or more explanatory variable. OLS estimates will be inconsistent and an instrumental variable technique, such as two-stage least squares (2SLS), should be used instead. In practice, the judgment about the presence of correlation between ε_t and explanatory variables is usually based more on theoretical considerations than on statistical tests.[39]

Correlation between the error term and explanatory variables in a regression equation arises when the explanatory variables are not *predetermined*; that is, when the value of the explanatory variable, in a given period, not only influences the contemporaneous value of the dependent variable but is, in turn, influenced by it. So we must consider whether each of the explanatory variables in equation (3) can safely be assumed to be predetermined or, instead, is likely to be simultaneously determined with the contemporaneous value of price.

Certainly the quadratic time trend terms are predetermined. (They might affect price in period *t* but are not affected by it.) Because the wholesale market for beef is national in scope, the price in this market, as proxied by AVGVAL, is probably relatively immune from the vagaries of cattle price in just one regional market. On this basis, we assume that AVGVAL is predetermined as well. We have argued in section V that the number of deliveries of non-cash cattle in week *t* are determined, by and large, in week *t* - 1 or earlier. Thus, while they conceivably might influence spot market price in period *t*, they would not be expected to be influenced by it.[40]

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[38]Loosely speaking, the property of "consistency" insures that the chances that the estimate of a parameter will err by more than any given amount will become vanishingly small as the size of the sample grows. Inconsistent estimators, on the other hand, can be subject to a systematic bias that does not vanish in the limit as sample size increases.

[39]There are statistical tests for correlation between the error term and explanatory variables in a regression equation. The most widely used such test is a version of Hausman's specification test. See Greene, section 16.8. The Hausman "exogeneity test" could be applied to determine whether the 2SLS estimates of equation (3) should be "favored" over the OLS estimates, or vice-versa. But that is not our objective here. We are merely interested in showing that regression analysis uncovers a statistically significant *ceteris paribus* negative relationship between spot market cattle prices and contemporaneous non-cash supply delivery volumes in weekly time series data, and that this finding is robust across estimation methods and definitions of the price and non-cash supply variables.

[40]It is distinctly possible, however, that non-cash cattle deliveries in week *t* are affected, not by price in week *t*, but by the expectation of week *t*'s price, formed in an earlier week. This possibility is specifically addressed in the analysis of section VIII.2.

That brings us to Q_t, the volume of cattle traded in the spot market in week *t*. On the one hand, it might be argued that the cattle reaching slaughter weight and finish in week *t* are perfectly inelastically supplied to the spot market; that is, are offered for immediate sale more-or-less regardless of price. Were this argument valid, Q_t could also be viewed as predetermined. On the other hand, it might be argued that feeders have an opportunity to shift cattle supplies from one week to another to take advantage of more favorable prices. In this event, Q_t and week *t*'s spot market price would be jointly determined, and Q_t would be correlated with the equation's error. These considerations lead us to undertake estimation of equation (3) using both ordinary least squares (OLS) and two-stage least squares (2SLS) and to compare the results of the two methods.[41]

Estimation of versions of equation (3) by OLS produced evidence of serial correlation in the error terms.[42] Consequently, equation (3) was estimated by the Yule-Walker procedure for correcting for errors of the first-order autoregressive (AR(1)) form.[43] Results are reported in Table VII.2.2 for a total of eight specifications: Each of the four dependent variables (AVGSPR, AVGHPR, AVGCPR, and ADJCPR) is employed with each of the two measures of non-cash supply deliveries (CSTOT and CSRAT).[44]

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[41]Actually, as will be explained presently, we estimate equation (3) by 2SLS and by the Yule-Walker procedure. The Yule-Walker procedure is an example of generalized least squares, or GLS. GLS amounts to OLS estimation of a transformed version of equation (3). The Yule-Walker procedure, in particular, entails a transformation that is appropriate for cases in which the error terms are serially correlated (ε_t and ε_s are correlated).

[42]For example, when CSTOT was used as the measure of non-cash supply deliveries, the values of the Durbin-Watson statistic were 0.726, 0.737, 0.725, and 0.741 for versions of the model with dependent variable AVGSPR, AVGHPR, AVGCPR, and ADJCPR respectively. Values such as these lead to rejection, at conventional significance levels, of the hypothesis of zero serial correlation in favor or the alternative of positive, first-order serial correlation. See Greene, section 13.5.1.

[43]The assumption of AR(1) errors appears to be an adequate characterization of the disturbance process: When the equations were re-estimated using the Yule-Walker procedure adapted to AR(2) errors, the regression parameter estimates differed little from those reported in Table VII.2.2 and the estimates of the second-order autoregressive parameters were invariably insignificant.

[44]The Table VII.2.2 estimates of "RHO" are those of the first-order autoregressive parameters in the specifications of the error process.

The possibility that Q_t may not be a predetermined variable in equation (3) (the possibility that Q_t and ε_t might be correlated) is accommodated by 2SLS estimation. This procedure essentially involves OLS estimation of a version of equation (3) in which Q_t, the explanatory variable suspected of being correlated with the error terms, is replaced by its projection on a set of "instrumental variables" that are more arguably uncorrelated with ε_t.[45] The results of 2SLS estimation of each of the model's eight versions are reported in Table VII.2.3.

One striking feature of the results reported in Tables VII.2.2 and VII.2.3 is the robustness of the findings with respect to the non-cash supply variable. In every case, the estimated coefficient of the volume of non-cash deliveries is significantly negative at the 1% level or better, especially when they are measured by the CSTOT variable. To get a feeling for the magnitude of the price effect of non-cash purchases, consider for example, the results obtained by the Yule-Walker procedure for the model with AVGSPR as the dependent variable (first two columns of Table VII.2.2). Suppose that the weekly volume of non-cash deliveries (CSTOT) were to increase from its mean value (about 26,400 head) by one sample standard deviation (about 7730 head). The estimation results, taken at face value, imply that the other-factors-held-fixed impact of this change would be a decrease in AVGSPR by \$0.69/cwt. If weekly non-cash cattle deliveries as a proportion of total weekly slaughter (CSRAT) were to increase from its mean value (about 0.29, or 29%) by one standard deviation (about 0.08, or 8%), the apparent other-factors-held-fixed effect would be a decrease in AVGSPR by \$0.54/cwt.[46] Relative to overall sample variability in price, the magnitude of this effect is "small." A \$0.60/cwt. change in the price of steers, for example, represents only about 16% of the 66-week sample standard deviation of steer prices and only about 3% of the range between the sample's minimum and maximum steer prices. On the other hand, a \$0.60/cwt. change in FOB feedyard prices would probably have a relatively significant impact on feeder profitability.

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[45]See Greene, section 16.5.2b. The instruments used for 2SLS estimation include AVGVAL, WEEK, WEEK2, one period lags of AVGVAL and Q, and current and one-period-lagged CSTOT, for those models with CSTOT as a regressor, or current and one-period-lagged CSRAT, for those models with CSRAT as a regressor.

[46]It is tempting to undertake similar calculations of the effect of non-cash purchases on price using the 2SLS estimation results. But if we really believe that regional price and quantity are jointly determined (the suspicion responsible for the decision to employ 2SLS estimation in the first place), it would be inappropriate to project the impact of a change in non-cash purchases on price *holding quantity constant*. The correct comparative static exercise in a simultaneous model would consider the impact of non-cash purchases on price and quantity jointly. This could only be done in the context of a complete model of price *and* quantity determination. We have not presented such a model here.

The regression results reported in Tables VII.2.2 and VII.2.3 support hypothesis 2 insofar as they uncover a particular empirical regularity between non-cash purchases and spot market price: Average price in the region's spot market for cattle tends to be relatively low in weeks in which delivery of cattle from non-cash sources are relatively high, other things equal. The policy relevance of this empirical regularity depends, however, on the nature of the economic mechanism responsible for generating it. In section VIII.2, we propose and investigate one particular intuitive model of the scheduling of non-cash deliveries which could account for the empirical relationships we have found in the data.

VIII. WHAT ECONOMIC MECHANISMS COULD BE BEHIND THE EMPIRICAL RELATIONSHIPS?

VIII.1. Price Discovery and the Distribution of Spot Market Transaction Prices

To interpret the results of the empirical analysis of section VII.1, one must distinguish between "price discovery" and "price determination." Following Ward:

> "Price determination is the interaction of the broad forces of supply and demand which determine the market price *level*. ... Price discovery is the process of buyers and sellers arriving at a transaction price for a given quality and quantity of a product at a given time and place, ... and begins with the market price level. Because buyers and sellers discover prices on the basis of uncertain expectations, transaction prices fluctuate around that market price level."

Consistent with this view, the price of fed cattle in any one regional market at any given date is characterized, not by a single point value, but by a distribution of values. The general location of the distribution, represented by its mean value, is determined, in Ward's words, "by the broad forces of supply and demand." But transaction prices on individual lots of cattle can depart from the regional average price for a variety of reasons.

First of all, individual lots of cattle can be priced above or below the market average price because of better or worse than average lot quality. This, of course, was the motivation for including several lot quality indicators among the explanatory variables in section VII.1's price regression. And, as is discussed in Appendix C, the estimation results for the coefficients of these quality indicators are generally consistent with the common-sense expectations that higher-than-average quality lots are rewarded with a premium and lower-than-average quality lots suffer a discount, relative to the regional average price. That is, within a given distribution of transaction prices, prices for cattle of "low" quality tend to fall on the left-hand-side of the distribution while prices